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Smear (Shutterless) Camera
Superquick Fuzes
T-2 Supplemental Charge

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Describes procedures for measuring the functioning time of impact fuzes for artillery, mortar, recoilless rifle, and tank ammunition with a high-speed framing camera and smear (shutterless) camera. It does not cover weapon-firing conditions, such as elevation, zone, temperature, and sample size.

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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-103
*Test Operations Procedure 4-2-807
AD No. A108586

8 December 1981

FUNCTIONING TIME OF IMPACT FUZES

1. SCOPE. The objective of this TOP is to provide procedures for measuring the functioning time of impact fuzes for artillery, mortar, recoilless rifle, and tank ammunition.

Impact fuzes are designed to detonate a round upon impact on the target. They are tested ballistically to determine the length of time that elapses between target impact and warhead detonation.

Impact fuzes are divided, according to response, into superquick, nondelay, and delay. A superquick fuze is a nose fuze which has been specially designed so that the sensing element causes immediate initiation of the charge (typically in less than 100 microseconds) upon impact. One of its primary uses is for high-explosive antitank (HEAT) ammunition. A nondelay fuze is one in which there is no intentionally designed delay, but when there is some inherent delay because of inertial components in the fuze which initiate the explosive train. This fuze is used when a small degree of target penetration is accept table or desired, and for graze action. A delay fuze contains a deliberately built-in delay element which delays initiation of the main charge after target impact. This fuze is used when the warhead is most effective if detonated after penetrating the target, such as a bunker. Some dual-purpose fuzes may be set for either delay or superquick functioning. This TOP covers superquick, nondelay, and delay fuzes. Weapon firing conditions such as elevation, zone, temperature, and sample size are covered in TOP 4-2-055.[1*]

*This TOP supersedes TOP/MTP 4-2-807, 28 December 1966.

[1*] Footnote numbers match those in Appendix B, References.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

Ammunition assembly plant
Weapons (as required)
Firing range
Temperature chamber
M36 electric detonators (for use at target)
Supplementary charge (T-2)[2]
Targets—plate with contact screens or 25- to 50-mm plywood

2.2 Instrumentation.

ITEM	MAXIMUM PERMISSIBLE ERROR OF MEASUREMENT*
Projectile velocity-measuring equipment (TOP 4-2-805[3])	$\pm 0.1\%$
Weapon pressure-sensing device (TOP 3-2-810[4])	$\pm 3\%$
High-speed framing cameras (speed varies from 500 to 32,000 frames per second (fps) for various fuze times - 12,000 up to 32,000 fps are required for superquick fuzes)	
Smear cameras	$\pm 1\%$
Electronic counter	± 1 microsecond
Electrical sequencer	

*Values may be assumed to represent ± 2 standard deviations; thus, the stated tolerances should not be exceeded in more than 1 measurement of 20.

3. REQUIRED TEST CONDITIONS. (See Paragraph 3, TOP 4-2-808.[5])

a. Carefully inspect the test items to ensure no damage has occurred in transit and that the items have no manufacturing defects. Record any such damage or deficiencies noted.

b. Inspect markings of fuze-setting directions for clarity.

c. Record the following information:

Nomenclature, serial numbers, and the manufacturer's name of the test fuzes.

Description of weapon used.

Description of projectile used.

Lot number of fuzes and projectiles, if standard manufacture, or type of loading, if projectiles are assembled locally.

d. Review the required technical and operational characteristics of the item under test, as stipulated in requirements documents such as Required Operational Capability (ROC), Training Device Requirements (TDR), and Letter Requirements (LR).

e. Review all instructional material issued with the test item by the manufacturer, contractor, or government, as well as reports of previous, similar tests conducted on the same type of test items.

f. Prepare data sheets for systematic entry of data, and chronology of test.

g. Since the time from impact to functioning for superquick and nondelay fuzes is very short, less than a millisecond, limit the permissible errors of measurement to microseconds.

h. Make arrangements to minimize the change in temperature between the time of removal from the conditioning chamber to the time of firing during all high- and low-temperature tests. A combination of overpack (conditioned with the ammunition) and a transport container is suggested. (See the final report of methodology investigation on Maintaining Temperatures during Tests of Ammunition.[6])

i. Ensure that all safety SOPs are observed throughout the test.

4. TEST PROCEDURES.

4.1 High-Speed Framing Camera Method. (primarily for indirect-firing artillery and mortars using ammunition with superquick and nondelay (point-detonating (PD) fuzes)

a. Set up the specified, vertical target at a range at which the fuze will be fully armed. (Typical target is 25- to 50-mm plywood.)

b. Emplace the firing weapon with barrel horizontal at the test site.

NOTE: Mortars (such as the 81-mm and 4.2-in.) not equipped with a standard firing mechanism will have to be modified with a mechanical trigger and a mounting system which permits firing horizontally.

c. Emplace velocity-measuring equipment. Instrumentation for measuring weapon chamber pressure is optional. (See TOPs 4-2-805 and 3-2-810 respectively.)

d. Install a high-speed framing camera adjacent to the target in a presurveyed position, and in such a manner that it is protected from blast and shock. Exact location varies according to the weapon caliber. (See Paragraph 2, Appendix A.)

e. Connect an electrical sequencer between the camera and the weapon.

f. Use an inert projectile, a propellant service charge (plus any other charges necessary for the test), a live fuze, and a T-2 supplemental charge. The propellant charge should be adjusted to provide a striking velocity which is typical of that expected in service. If circumstances do not permit the use of the T-2 charge, which substantially enhances the flash, live ammunition (105 mm and less) may be used to provide flash sufficient to avoid a substantial degradation in measurement accuracy.

NOTE: The T-2 supplemental charge is not used with mortar shells 81 mm and smaller; there is no room for it in the projectile. Thus live HE projectiles are used.

g. Set fuze for desired function.

h. Provide for chamber pressure measurements. (See TOP 3-2-810.)

i. Load the weapon; apply power to instrumentation; start the camera, and fire using an electrical firing box for electric primers or a solenoid for percussion primers. (A lanyard is not desirable because it will not provide proper timing with the camera.) Mortars positioned horizontally will require the so-called "A-frame trombone" to permit loading the weapon without the loader being in front of the weapon. It is an aluminum, U-shaped device that somewhat resembles a trombone. The shorter arm which pushes the round into the mortar has special fittings for 60- and 81-mm mortar rounds, and the longer arm is the handle which allows the loader to put a round in the mortar while beside or behind the mortar tube.

j. Continue photographing until functioning of the fuze has been completed.

k. Perform tests with items at 63° C (145° F), -51° C (-60° F), and 21° C (70° F), ±1.5° C (±2.5° F) with 10 rounds or other specified number, fired at each temperature.

l. Repeat steps e through k above, as necessary, to obtain the required data or to resolve incongruities.

NOTE: Fuzes set for delay function may also be measured by this method, provided enough distance is covered behind the target by the camera—9 to 15 m. Timing marks or framing rate may be used for "time of function"; "distance behind target" can be read visually from the film using stakes put in the ground at known intervals. (Stakes should be off the line of fire to reduce damage, but should be "sighted in" from the camera to equal the known distances under line of fire.)

4.2 Smear (Shutterless) Camera Method. (primarily for direct-firing tank guns using ammunition with nondelay (point initiating base detonating (PIBD), and base detonating (BD) fuzes fired against steel plate targets)

a. Set up the target at a downrange distance at which the fuze will be fully armed. For antitank projectiles, one-half of the available projectiles will be fired at a plate positioned at 0° obliquity, and one-half at a plate at 60° obliquity to assure that target obliquity has no effect on functioning time.

NOTE: When fuze action alone is of concern, 50-mm conventional (nonarmor) steel is preferred in order to reduce costs, in which case the projectile will be inert. (If armor penetration (TOP 4-2-812 7) and fuze action are being studied simultaneously, the target must be steel armor of the appropriate thickness, and the projectile must be live.)

b. Emplace the firing weapon with barrel horizontal at the test site. (See NOTE following step 4.1b above.)

c. Install a Smear camera adjacent to the target in a presurveyed position, and in such a manner that it is protected from blast and fragments. (See Paragraph 3, Appendix A.)

d. Connect an electrical sequencer between the camera and the weapon.

e. Set up instrumentation to measure muzzle velocity, and if pressure is required, use an appropriate system (e.g., copper crusher gages) for measuring chamber pressure. (See TOPs 4-2-805 and 3-2-810 respectively.)

f. Calibrate a sampling of M36 detonators as outlined in Paragraph 3, Appendix A, and record the delay constant of the detonator.

g. Install a "quick switch" wire screen in the area of expected impact. (See Paragraph 3, Appendix A.)

h. Connect a calibrated M36 detonator to the wire screen and high-voltage circuit as shown in Figure 1, and position the detonator in front of the target, under the expected flight path, and at a distance equal to the distance between the projectile nose and the center of the explosive booster.

NOTES: 1. For HE projectiles, the booster is within the ogive of the projectile. For HEAT and HEP projectiles, the booster is in the base end, as shown in Figure 1.

2. In the event there is uncertainty concerning the location on the projectile where the flash initiates (i.e., is it opposite the center of the booster?), prior to the fuze functioning test, statically detonate the projectile while viewing it with a Smear camera.

i. Use a propellant charge, which will give a striking velocity typical of that expected in service, an inert projectile, a live fuze, and a live booster. (See NOTE in Paragraph 4.2a.)

j. Set fuze (if required) for desired function.

k. Load the weapon; apply power to instrumentation; start the camera, and fire with an electrical firing box or an electric solenoid, as appropriate. (For mortars see step 4.1i.)

l. Continue photographing until functioning of the fuze has been completed.

m. Conduct tests at 63° C, -51° C, and 21° C, +1.5° C with 10 rounds or other specified number fired at each temperature, half at each target.

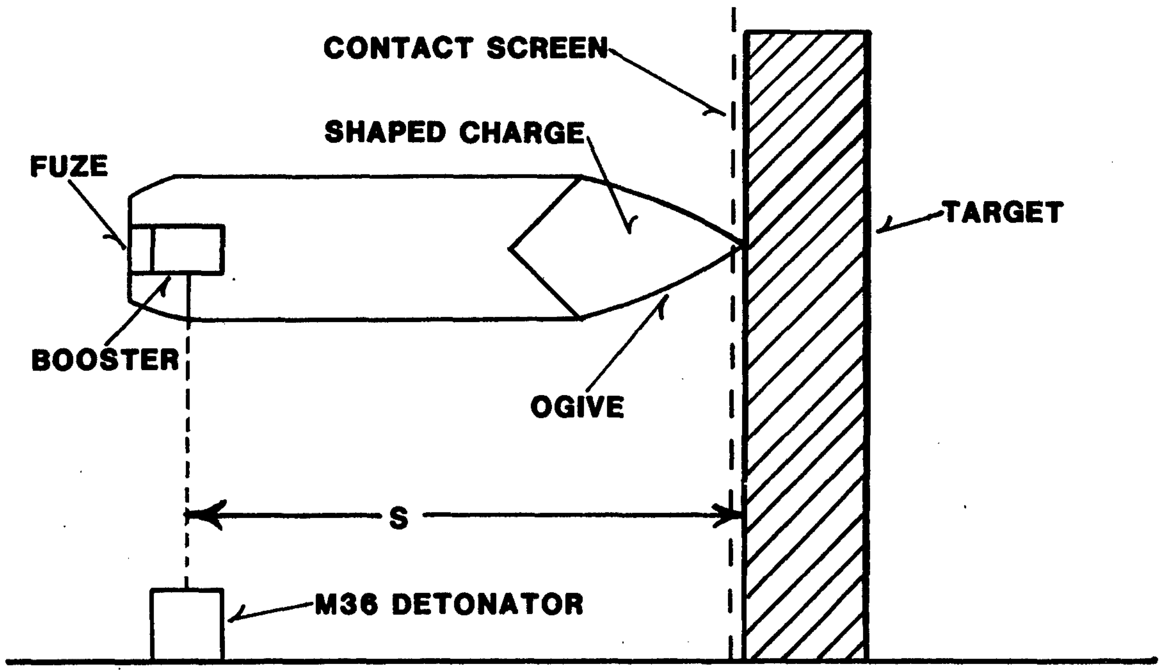

Figure 1. Target Setup for Vertical Target
(A similar setup is suitable for the 60° obliquity target.)

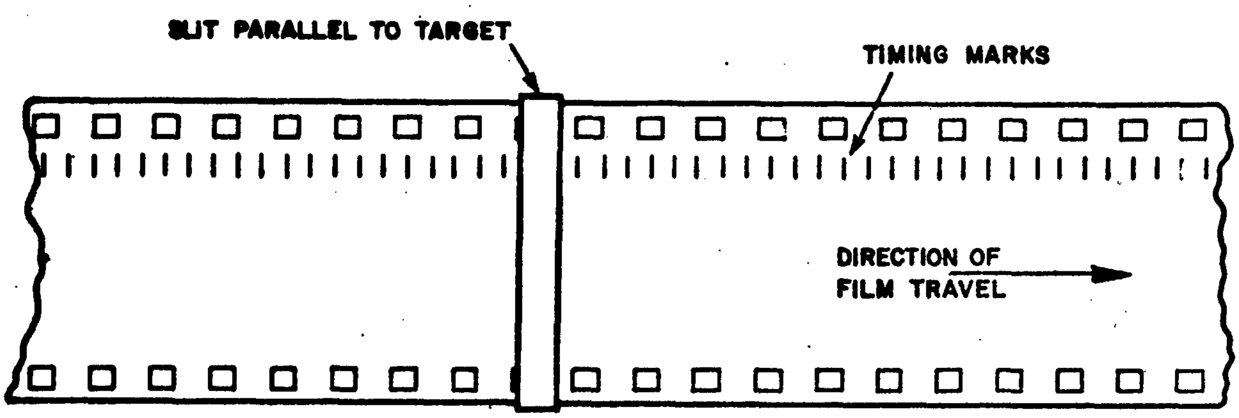

Figure 2. Relationship of Aperture Slit & Film Travel to Target Setup.

n. Repeat steps d through m above, as necessary, to obtain the required data or to resolve incongruities.

5. DATA REQUIRED. In addition to specific instructions listed for each subtest, record the following in a chronological engineering logbook:

a. Pertinent remarks and observations to aid in subsequent analysis of test data.

b. Projectile temperature.

c. Weapon chamber pressure.

d. Muzzle velocity.

5.1 High-Speed Framing Camera Data. Record the following:

a. Target description and obliquity.

b. Fuze-functioning data from film reading.

5.2 Smear (Shutterless) Camera Data. Record the following:

a. Target description and obliquity.

b. Detonator delay constant.

c. Fuze-functioning data from film reading.

6. PRESENTATION OF DATA.

6.1 High-Speed Framing Camera Data. Determine the camera operating rate as indicated by recorded time intervals. Count the number of frames from impact to beginning of functioning. The accuracy of the time interval (framing rate) of this method is dependent upon the picture-taking frequency at the time of the action. The projectile may impact the target while the shuttering of the film is taking place, and likewise, the detonation may occur during a "blind" time (time between frames). The time interval between two events can only be determined to within plus or minus one frame. For example, a framing rate of 10,000 per second can resolve a time interval to within 0.0001 second. A projectile at 1000 m/s will travel 0.1 meter during this period. Thus, the high-speed camera of 10,000 frames per second should not be used when a measurement of less than 0.0001 seconds is required.

6.2 Smear (Shutterless) Camera Data. Smear camera data are obtained by measuring the linear distance on the film from the detonator flash to the projectile flash. The film speed is obtained from the timing marks on the film (Figure 3). A frequency of 10,000 pulses per second is generally used. Determine the following:

d = longitudinal distance on film between M36 detonator flash image and booster flash image (millimeters).

Δx= distance between timing marks on film (millimeters).

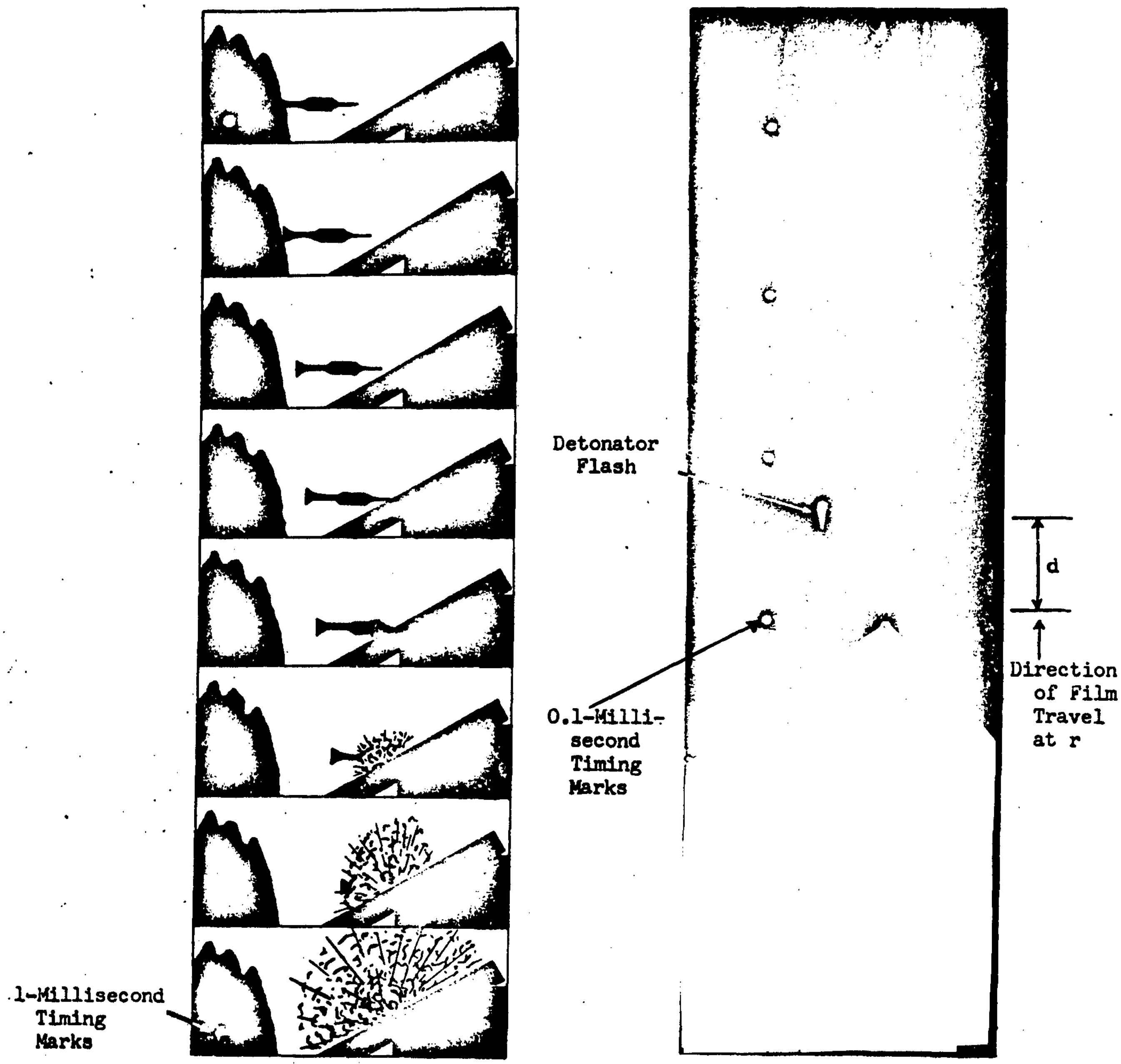

Figure 3. Representative Photograhic Records of Fuze Functioning
Left: Framing Camera Record. Right: Smear Camera Record

Δt= time interval between timing marks on film (microseconds).

r = film speed (millimeters per microsecond).

c = M36 detonator delay time (microseconds).

M = time interval derived from the horizontal displacement of the booster from the M36 detonator at the time of functioning (microseconds).

v = projectile velocity (millimeters per microsecond).

D = distance from centerline of projectile trajectory to the camera lens (millimeters).

f = focal length of lens (millimeters).

i = linear film displacement of the booster flash image from the detonator flash image at the apparent function time (millimeters).

t = apparent fuze-functioning time (microseconds).

m = lens magnification factor.

The film speed is equal to the distance between timing marks divided by the time interval = $r = \Delta x/\Delta t$.

Since the contact between the "quick switch" wire screen and the target initiates the M36 detonator, the fuze and the detonator are initiated simultaneously. Thus the apparent fuze-functioning time is equal to the linear distance, d, between the detonator and booster flash images divided by the film speed, r, plus the M36 detonator delay time, c.

$$t = d/r + c$$

At the time of initiation, the booster and the M36 detonator are the same distance from the target as shown in Figure 1. However, due to the fuze delay time, the booster will be closer to the target at time of functioning than the M36 detonator by a distance equal to the projectile velocity, v, times the apparent fuze-functioning time, t.

Based on the Gaussian lens formula, the lens magnification factor (image size divided by object size) is given by

$$m = \frac{f}{D-f}$$

Thus the physical displacement of the booster flash image from the M36 detonator flash image due to projectile movement alone during apparent functioning time, t, is

$$i = mvt$$

Since the film and projectile are moving in the same direction, the inverted image formed by the lens will cause this displacement to be added to the distance between the detonator and booster flash images. Thus the time equivalent of this

distance, $M = i/r$, must be deducted from the apparent functioning time to obtain the true fuze-functioning time:

Fuze-functioning time = t - M

Example:

$v = 914.4$ m/sec = 0.9144 mm/microsecond

$D = 30.48$ m = 30480 mm

$f = 35$ mm

$\Delta t = 0.1$ microsecond = 100 microseconds

$\Delta x = 3.8$

$d = 3.0$

$c = 21$ microseconds

$$r = \frac{\Delta x}{\Delta t} = \frac{3.8}{100} = 0.038 \text{ mm/microsecond}$$

$$t = \frac{d}{r} + c = \frac{3.0}{0.038} + 21 = 100 \text{ microseconds}$$

$$M = \frac{fvt}{r(D-f)} = \frac{(35)\ (0.9144)\ (100)}{(0.038)\ (30480 - 35)} = 2.8 \text{ microseconds}$$

Fuze-functioning time = t - m = 100 - 2.8 = 97.2 microseconds

This Smear camera technique is capable of providing data having an accuracy of 5 microseconds. The film travel rate and the accuracy of positioning the M36 detonator are the prime factors in determining the accuracy of the data.

Equipment evaluation usually will be limited to comparing the actual test results to the equipment specifications and the requirements as imposed by the intended usage. The results may also be compared to data gathered from previous tests of similar equipment.

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APPENDIX A

CAMERA TECHNIQUES

1. GENERAL. Two photographic methods are available to measure the time from impact to rupture of the projectile body. Both methods employ high-speed cameras, and the method selected depends upon the anticipated time interval from the impact to the detonation of the projectile and the accuracy of the data desired.

The following paragraphs describe these two methods and the instrumentation used with them.

2. HIGH-SPEED FRAMING CAMERA METHOD. The shutter-type camera is of the continuously moving-film type, and the shuttering is produced by a rotating prism. The camera is positioned in the plane of the target face with the optic axis aimed across the face of the target. Regardless of the location of the impacts across the target, the camera will record the target surface as a line and a side-view silhouette of the projectile. Best results are obtained when the sky or a light-colored panel is used as a background.

3. "SMEAR" CAMERA (SHUTTERLESS) METHOD. The "Smear" camera has no shutter or prism, therefore, no blind time, and the film moves continuously past a narrow-slit aperture which defines the space position of the area to be photographed. Instead of recording an image of the projectile, this camera records two flashes of light. The first flash is produced by an M36 detonator attached to a wire screen on the surface of the target. The impacting projectile closes a circuit which initiates the detonator by a high-voltage discharge (1000 volts dc). The second flash is produced by the live fuze.

The camera uses a short-focal-length lens and is positioned approximately 30 meters (100 feet) to the left side of the line of fire, (or on the right side if the scene is viewed through a mirror), slightly downrange from the face of the target (slit aperture parallel to the target as indicated in Figure 2). (Exact location varies according to the weapon caliber.) The camera should photograph at least one projectile length and not more than one and one-half projectile lengths on the impact side of the target. The remainder of the field of view is behind the target.

NOTE: The camera location is specified to provide optimal direction of film motion relative to the projectile image motion for available camera equipment. If this method is not followed, the sign of the correction term M will be incorrect in the equations in Paragraph 6.2.

The area of expected impact is covered with wire screen insulated from the target (Figure 1). The screen is connected to the high-voltage circuit and serves as a quick switch when the projectile nose pushes it against the target which is the ground side of the circuit.

The M36 electric detonator is connected to the screen and a high-voltage circuit. It is positioned in front of the target beneath the expected flight path, and at a distance from the target equal to the distance between the projectile nose and the explosive booster. Incorrectly positioning the detonator 25.4 mm (1 in.) can be equivalent to 1 microsecond of time when using the short lens and long distance. (See also Paragraph 4.2h.)

The M36 detonators used in the process are calibrated to obtain a delay constant. The calibration consists of sampling a detonator lot by measuring the time from voltage application to detonation. The detonators are connected into an electronic counter which is started by the same action (high-voltage circuit closure) that ignites the detonator. The counter is stopped by the detonator explosion, when an area of the detonator becomes conductive by ionized, gaseous, explosive byproducts. The energy available to the detonator during the calibration should be equivalent to the energy available during the test. Accordingly, the same equipment or equipment having identical values of dis- charge voltage and capacitance should be used for both operations. The length and gage of connecting leads to the M36 detonator should be chosen to minimize energy loss due to voltage drop in the leads. (See Paragraph 6.2 for method to obtain fuze time from the film.)

APPENDIX B

REFERENCES

1. Test Operations Procedure 4-2-055, Fuzes, 3 December 1970.

2. Final Report of Methodology Investigation on Evaluation of Spotting Charges for Point-Detonating Fuzes, APG-MT-4962, TRMS 7-CO-PB7-AP1-002, 8 July 1977, APG, TECOM.

3. Test Operations Procedure 4-2-805, Projectile Velocity Measurements, 23 April 1979.

4. Test Operations Procedure 3-2-810, Weapon Pressure Measurements, 5 October 1979.

5. Test Operations Procedure 4-2-808, Functioning Time of Air-Burst Fuzes, 20 February 1981.

6. Final Report of Methodology Investigation on Maintaining Temperatures during Tests of Ammunition, APG-MT-5030, TRMS 7-CO-PB6-AP1-003, May 1978, APG, TECOM.

7. Test Operations Procedure 4-2-812, Penetration Tests of HEAT Warheads, 6 October 1980.